Journal of Advances in Environmental Health Research

Assessment of Birjand flood plain water quality by physico-chemical parameters analysis in Iran

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Original Article

Abstract

We assessed the physico-chemical status of twelve surface water samples from the Birjand flood plain (east of Iran) during fall 2010. The sampling points were selected on the basis of their importance. The physico-chemical parameters such as pH, temperature (T), electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), chloride (Cl^{-}), sulphtate (SO_4^{2-}), bicarbonate (HCO_3^{-}), carbonate (CO_3^{2-}), nitrite (NO_2^{-}), nitrate (NO_3^{-}), dissolved oxygen (DO), biochemical oxygen demand (BOD_5), and chemical oxygen demand (COD) of surface water were determined. The results showed that there were a statistical significant positive correlation between the pH and DO. pH and temperature indicated negative association with most of the parameters. Furthermore, EC showed highly significant positive association with TDS, TH, Ca^{2+}, Na^{+}, and Cl^{-}. Results showed that the quality of surface water was not suitable for drinking, with references to the concentrations of EC, TDS, TH, Na^{+}, HCO^{3-}, and BOD_5 which were more than the prescribed limits, in most sites.

KEYWORDS: Water Quality, Hardness, Biochemical Oxygen Demand, Birjand Flood Plain

Date of submission: 9 June 2013, ***Date of acceptance:*** 12 September 2013

Citation: Mansouri B, Moussavi SP, Salehi K, Salehi J, Kardan-Moghaddam H, Mahmoodi M, et al. **Assessment of Birjand flood plain water quality by physico-chemical parameters analysis in Iran.** J Adv Environ Health Res 2013; 1(2): 101-11.

Introduction

Today, the competition for scarce water resources is intense both in Iran and in many places all around the world; because water is the most essential commodity for human consumption and is one of the most important renewable resources, which must be prevented from deterioration in quality. The eastern part of Iran has a semi-arid climate with average annual rainfall of 171 mm. Therefore, communities must share freshwater sources from aquifer natural resources. Water source is one of the most important limiting factors in arid and semi-arid regions that can exhibit the development of sustainable population growth.[1] Many people around the world enjoy the benefits of technological and economic developments and

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high standards of living; however, many scientists are aware that these developments cause lots of issues such as bioenvironmental problems specially water resources pollution.

Human activities can have direct or indirect contaminating effect on drinking water resources such as streams, rivers, lakes, dams, reservoirs, and groundwater.[2] The main sources of water pollution are discharge of domestic sewage and industrial effluents -which contain organic pollutants-chemicals and heavy metals, and run-off from land-based activities.[3] Increasing water pollution causes not only the deterioration of water quality but also threatens human health and the balance of aquatic ecosystems, economic development, and social prosperity.[4] Given the effects of human activities on water quality, it is necessary to notice the quality of water resources.[5] Monitoring can be the first and the most important step toward applying an appropriate quality management plan in order to eliminate water pollution.[6] A large number of physico-chemical parameters can fluctuate the quality of water resources, and monitoring these parameters can strongly be affected by magnitude and source of pollution.[7] Assessment of water resource quality in any region is an important aspect of its developmental activities, because rivers, lakes and man-made reservoirs are water supplies for domestic, industrial, and agricultural applications.[8] Hence, the objective of this article was to investigate the physico-chemical parameters (pH, temperature (T), electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, HCO_3^{-}, CO_3^{2-}, NO_2^{-}, NO_3^{-}, dissolved oxygen (DO), biochemical oxygen demand (BOD5), and chemical oxygen demand (COD) and Wilcox and Schoeller diagrams of surface water in Birjand flood plain, east of Iran. The analyzed data were compared with standard values recommended by the World Health Organization (WHO) for drinking purposes.[9]

Materials and Methods

The studied site was located in Birjand, east of Iran, and is the capital city of Southern Khorasan province. It is situated at latitude of 32˚ 86' N and longitude of 59˚ 21' E and is about 1490 m above the sea level (Figure 1). The climate of the city is semi-arid with cold winter and approximately 8 months dry season (from middle of April to December). Its average rainfall is 171 mm and unevenly distributed throughout the year. The average annual temperature is 16.5° C with the warmest month in July (average 28.5° C) and the coldest in January (average 3.5° C). The sunlight duration in a year is 255 days.

Water samples were collected from 12 stations, three samples from each of them in the Birjand flood plain during fall 2010. Water samples were collected in acid washed 250-ml plastic bottles. The samples were kept in refrigerator at 4° C. The water samples were filtered using a 0.45 µm nitrocellulose membrane filter. Prior to any analysis, all the equipment and containers were soaked in 10% HNO_3 and rinsed thoroughly with deionized distilled water before use. Water temperature was measured during sampling using an ordinary thermometer. The physico-chemical parameters such as pH, EC, TDS, TH, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, HCO_3^{-}, CO_3^{2-}, NO_2^{-}, NO_3^{-}, DO, BOD, and COD were determined using standard methods[10] (Table 1). Finally, the resulted data were compared with the WHO standards specified for the maximum rate of physicochemical parameters allowed in drinking water. Statistical analyses were carried out using Excel and SPSS for Windows (version 16.0, SPSS, Inc., Chicago, IL, USA) and the Pearson correlation (*r*) was used to test correlations. All the concentrations were reported in mg/l except for pH, EC (in micromhos/ cm), and temperature (in ° C).

Results and Discussion

pH and water temperature

Measurement of pH is one of the most important and frequently used tests in water chemistry. pH is an important factor in determining the chemical and biochemical properties of water. It

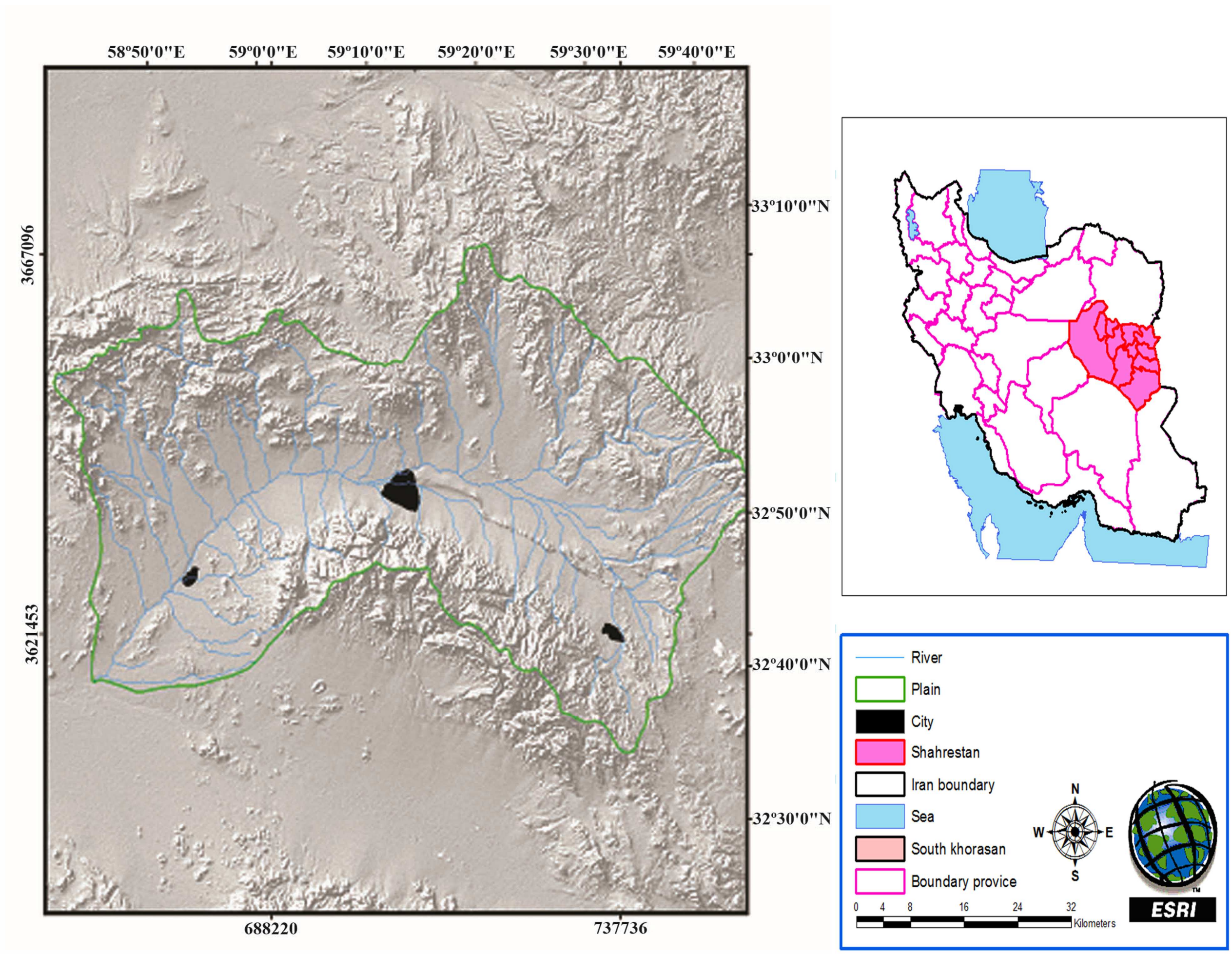

Figure 1. Map of the study area (Birjand, Iran flood plain)

Table 1. Methods used for estimation of physicochemical parameters

Parameters	Test methods
pH	Multi Parameter Analyzer (Consort, Model: C534T & Istek, Model: pdc815)
EC	Multi Parameter Analyzer (Consort, Model: C534T & Istek, Model: pdc815)
TDS	Multi Parameter Analyzer (Consort, Model: C534T & Istek, Model: pdc815)
TH	Titration method
Ca^{2+}	Titration
Mg^{2+}	Titration
Na^{+}	Flame Photometric method
K^{+}	Flame Photometric method
Cl^{-}	Argentometric titration
SO_4^{2-}	Photometer
HCO_3^{-}	Titration
CO_3^{2-}	Titration
NO_2^{-}	Photometer
NO_3^{-}	Photometer
DO	Multi Parameter Analyzer
BOD_5	5 days incubation at 20 °C and titration of initial and final DO
COD	Open reflux method

EC: Electrical conductivity; TDS: Total dissolved solids; TH: Total hardness; DO: Dissolved oxygen; BOD_5: Biochemical oxygen demand; COD: Chemical oxygen demand can almost have chemical effects on most water substances.[11] pH of surface water was alkaline, with an average value of 8.3 (Table 2). They were (total of stations) within the WHO standard values for pH in drinking water (6.5-9.5).

Temperature is another important factor and all life processes are accelerated or slowed down by temperature changes in the environment. It influences the solubility of gases and salts in water. Most chemical equilibrium is temperature dependent. Important environmental examples are the equilibrium between ionized and unionized forms of ammonia, hydrogen cyanide, and hydrogen sulfide.[11] The water temperature recorded from surface water Birjand flood plain showed only slight variations. Average water temperature of surface water varied from 25.4° to 27.8° C (Table 2).

TDS

TDS indicate the general trend of the surface quality or salinity of the surface water bodies. In natural waters, the major contributors to TDS are carbonate, bicarbonate, chloride, sulfate, phosphate, and nitrate salts.[11] During the present study, minimum and maximum values of TDS were recorded at stations 9 (1145 mg/l) and 8 (2960 mg/l), respectively. This may be due to natural sources and urban runoff from the sampling stations.[12] Water with a TDS < 1200 mg/l generally had an acceptable taste. Higher TDS could adversely influence the taste of drinking water and may have a laxative effect.[11]

Total hardness, calcium and magnesium (Ca^{2+}, Mg^{2+})

Total hardness ranged from 339-893 mg/l as $CaCO_3$. The highest and lowest values were recorded at stations 8 and 9, respectively (Table 2). It might be due to the dissolution of land derived carbonates and bicarbonate in the water. The concentrations of Ca^{2+} and Mg^{2+} observed from the studied area varied from 30-200 mg/l as $CaCO_3$ and 42-148 mg/l as $CaCO_3$, which are below the standard limits of 200 and 150 mg/l as $CaCO_3$ in the surface water samples respectively. Ca^{2+} is an important ion to develop proper bone growth. Although Mg^{2+} is an essential ion for functioning of cells in enzyme activation, it is considered as laxative agent at higher concentration.[13]

Sodium (Na^+)

Sodium varied from 91 to 651 mg/l, the amount which exceed the maximum permissible limit i.e. 200 mg/l for drinking water prescribed by WHO (Table 2). It makes the water unsuitable for drinking, because it causes severe health problems e.g. hypertension.[14] Surface water in most of the study area comes under the non-safe zone for drinking, with reference to the concentration of Na^+. Therefore, sodium restricted diet is suggested to the patients suffering from heart diseases and kidney problems.[13]

Potassium (K^+) and Chloride (Cl^-)

Potassium in collected water samples lies in the range from 1.1 to 1.8 mg/l. It maintains the fluid balance in the body. High potassium values may cause nerviness and digestive disorder. Chloride varied from 266 to 923 mg/l. The amount presented do exceed the maximum permissible limit i.e. 600 mg/l for drinking water prescribed by WHO. On the other hands, the chloride levels in unpolluted waters are often below 10 mg/l[15], but mean concentrations observed in this study ranged from 266 to 923 mg/l. In high concentrations, chlorides in urban areas are indicators of large amounts of non-point pollution; pesticides, grease and oil, metals, and other toxic materials with high levels of chloride.

Bicarbonate (HCO_3^-)

The results showed that the concentration of HCO_3^- (336 to 671 mg/l) was 1.12 to 2.23 times higher than that of the desirable limit (300 mg/l) in the surface water (Table 2). HCO_3^- has no known adverse health effects on human health, if it exceeds 300 mg/l in the drinking water.[16] However, it should not exceed 300 mg/l in the potable water, as it may lead to kidney stones in the presence of higher concentration of Ca^{2+}, especially in dry climatic regions.[13]

Table 2. Levels of the physico-chemical parameters (mean ± SD*) in surface water samples

	Station												Mean ± SD	WHO 2008
	1	2	3	4	5	6	7	8	9	10	11	12		
pH	8.5 ± 0.2	8 ± 0.2	8 ± 0.1	8.6 ± 0.4	8.1 ± 0.3	8.9 ± 0.2	8.7 ± 0.2	8.2 ± 0.1	8.4 ± 0.1	8.1 ± 0.4	8.5 ± 0.4	8.7 ± 0.3	8.3 ± 0.2	6.5-9.5
T	15 ± 0.7	17 ± 0.5	16 ± 1.2	16 ± 01.4	15 ± 0.5	15 ± 0.4	16 ± 0.8	15 ± 0.5	16 ± 0.6	16 ± 01.1	15 ± 01.3	17 ± 0.5	15.7 ± 0.7	-
EC	3820 ± 40	1983 ± 37	2710 ± 15	1848 ± 12	1798 ± 23	2650 ± 35	2350 ± 18	4640 ± 44	1794 ± 25	4000 ± 38	3820 ± 50	1948 ± 18	2780 ± 29	1400
TDS	2440 ± 41	1267 ± 33	1731 ± 31	1180 ± 27	1150 ± 25	1690 ± 29	1500 ± 37	2960 ± 46	1145 ± 23	2552 ± 48	2440 ± 34	1383 ± 31	1786 ± 34	1000
TH	594 ± 16	394 ± 17	542 ± 13	342 ± 11	694 ± 15	346 ± 13	741 ± 21	893 ± 16	339 ± 13	642 ± 17	594 ± 24	370 ± 14	541 ± 217	500
Ca^{2+}	110 ± 10	90 ± 7	110 ± 8.4	50 ± 6	80 ± 6	30 ± 3	30 ± 5	200 ± 11	50 ± 6	120 ± 13	110 ± 8	70 ± 7	86 ± 8	200
Mg^{2+}	78 ± 6.1	42 ± 4	66 ± 5.9	54 ± 3.1	120 ± 7	66 ± 3	148 ± 7	72 ± 5	54 ± 6	84 ± 5	78 ± 6	54 ± 3	75 ± 5	150
Na^{+}	602 ± 28	270 ± 24	370 ± 31	262 ± 27	91 ± 15	447 ± 21	194 ± 11	651 ± 30	250 ± 17	620 ± 25	602 ± 20	270 ± 16	385 ± 23	200
K^{+}	1.3 ± 0.2	1.4 ± 0.3	1.3 ± 0.1	1.2 ± 0.4	1.1 ± 0.4	1.5 ± 0.1	1.7 ± 0.1	1.8 ± 0.2	1.6 ± 0.2	1.1 ± 0.1	1.3 ± 0.1	1.3 ± 0.2	1.3 ± 0.2	10
Cl^{-}	834 ± 27	301 ± 21	639 ± 31	266 ± 26	372 ± 34	532 ± 28	408 ± 32	674 ± 29	301 ± 20	923 ± 37	834 ± 29	286 ± 19	530 ± 28	600
SO_4^{2-}	321 ± 30	144 ± 15	124 ± 17	240 ± 14	43 ± 6	168 ± 7	240 ± 13	100 ± 8	117 ± 9	264 ± 9	321 ± 15	230 ± 18	192 ± 013	400
HCO_3^{-}	488 ± 21	671 ± 33	396 ± 18	366 ± 27	337 ± 19	487 ± 31	427 ± 24	427 ± 17	427 ± 29	518 ± 21	488 ± 34	377 ± 25	454 ± 25	300
NO_2^{-}	0.01	0.02	0.02	0.01	0.02	0.08	0.07	0.01	0.06	0.01	0.01	0.01	0.02	< 0.1
NO_3^{-}	11.7 ± 0.5	19.9 ± 0.8	5.1 ± 0.5	2.8 ± 0.2	2.7 ± 0.2	8.2 ± 0.6	10.1 ± 0.3	11.6 ± 0.4	11.7 ± 0.2	2.8 ± 0.1	11.7 ± 0.4	3.8 ± 0.3	8.5 ± 0.4	45
DO	9.4 ± 0.4	3.7 ± 0.5	6.9 ± 0.2	15.5 ± 0.4	2.5 ± 0.1	10.3 ± 0.5	7.1 ± 0.4	1.9 ± 0.1	2.4 ± 0.1	8.5 ± 0.2	9.4 ± 0.2	13.5 ± 0.4	7.5 ± 0.3	-
BOD_5	15 ± 01.1	9.5 ± 0.7	15.6 ± 0.7	7 ± 0.3	9 ± 0.5	14 ± 0.9	14 ± 0.6	10 ± 0.8	10 ± 0.8	11 ± 0.7	15 ± 01.2	8 ± 0.4	11.5 ± 0.7	-
COD	9.9 ± 0.5	18 ± 0.8	16.9 ± 0.6	11 ± 0.4	15 ± 0.2	18 ± 0.7	24 ± 1.2	15 ± 1.1	15 ± 0.8	33 ± 3.2	9.9 ± 1.2	13 ± 1.2	16.5 ± 0.6	-

(All parameters are in mg/l except pH, T and EC in micromhos/cm, Temperature in ^{o}C; *Standard deviation); T: Temperature EC: Electrical conductivity; TDS: Total dissolved solids; TH: Total hardness; DO: Dissolved oxygen; BOD_5: Biochemical oxygen demand; COD: Chemical oxygen demand

Nitrate (NO_3^-) and nitrite (NO_2^-)

Maximum concentration of NO_3^- was observed at station 2 and minimum was at station 5 (Table 2). Presence of NO_3^- ion could be due to the anthropogenic sources, namely; domestic sewage, agricultural wash off and other waste effluents containing nitrogenous compounds.[17] A high NO_3^- concentration in water not only induces environmental eutrophication under certain conditions, but also is a causative factor in methemoglobinemia and cancers.[18,19]

Dissolved oxygen (DO)

The value of DO in our samples fluctuated from 1.9 mg/l to 15.5 mg/l (Table 2). The maximum values were recorded at station 4 and minimum values were at station 8. The high DO is due to increase in temperature and duration of bright sunlight influence on the percentage of soluble gases (O_2 and CO_2).[20]. Oxygen is one of the most important gases in any living ecosystem. The amount of dissolved oxygen in water depends on temperature. Dissolved oxygen is an important factor in assessing water quality. Dissolved oxygen is consumed by the degradation (oxidation) of organic matters in water.[21]

Biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD)

The biochemical oxygen demand ranged from 7 to 15.6 mg/l and chemical oxygen demand was between 9.9 and 33 mg/l (Table 2). Measurement of BOD has long been the basic means of determining the degree of organic pollution in aquatic systems, and a river is said to be unpolluted if its water has a BOD_5 of 2 mg/l or less.[22] BOD is an indicator of the potential for a water body to become depleted in oxygen and possibly become anaerobic because of biodegradation. Water with a high BOD may not support aquatic life, unless there is a means for rapidly replenishing dissolved oxygen.[11]

Wilcox and Schoeller diagram

Wilcox diagram is based on the relationship between the EC and SAR of irrigation water on agricultural land. This diagram is classified into different categories (SAR: S1 to S4 and EC: C1 to C4) based on the water conation in soil.[22] The result of this study showed that the water quality of surface water was suitable for irrigation (except station 7 and 8; Figure. 2). These two sources are located in the region of Birjand plain output, so the concentrations of solutes in these two sources were higher than the other stations.[23] High level of these elements would cause leaf blight, reduce production efficiency and product quality.[24] These two sources of water (according to the amount of salt and sodium in water) need essential actions in agriculture section including irrigation reduction, increased leaching, using drip irrigation system with proper filtration.[25]

Schoeller diagram which is based on the concentration of the major cations and anions with water hardness play an important role in the situation of drinking water in a region.[26-27] These parameters are set according to WHO standards and it can be used to establish a relationship between the lines to identify areas suitable for drinking. Station 7 was found unsuitable for drinking purpose because of high concentration of sulfate (Figure 3). Therefore, it is recommended to apply chemical treatment to meet the drinking water standard.

In order to quantitatively analyze and confirm the association among physico-chemical parameters of surface water samples, Pearson's correlation analysis was applied to the data (Table 3). Direct correlation exists when increase or decrease in the value of one parameter is associated with a corresponding increase or decrease in the value of other parameter.[28] A significant positive association was found between pH and DO. pH and temperature showed negative correlation with most of the parameters. EC showed highly significant positive correlation with TDS, TH, Ca^{2+}, Na^+, and Cl^-. This suggests that electrical conductivity depends on dissolved solids which depend on salts compound[29], such as NaCl, $CaCl_2$. The strong positive correlation (r = 0.89)

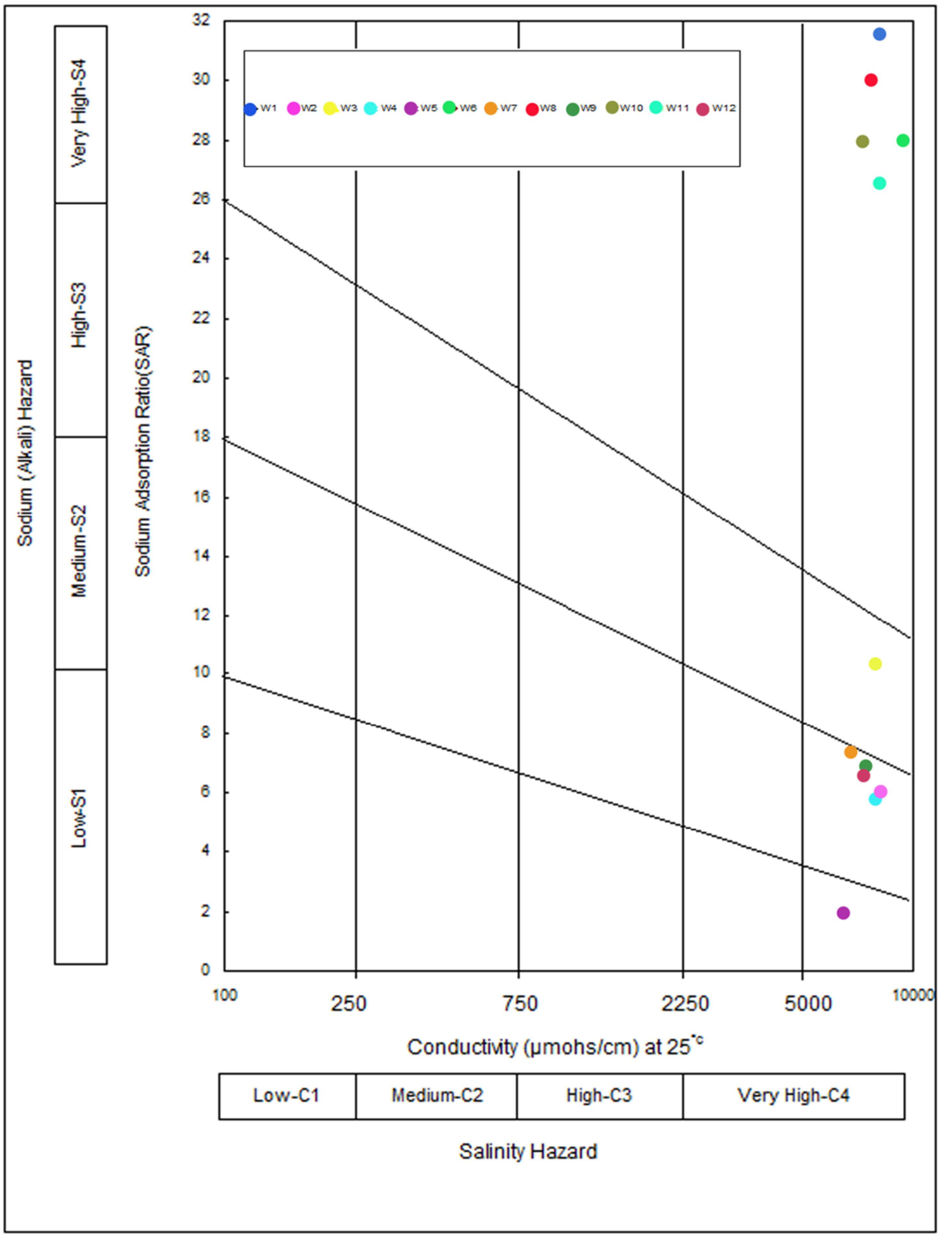

Figure 2. Wilcox diagram of Birjand, Iran f1ood plain

between electrical conductivity, TDS and chloride reflects the fact that chloride increases the electrical conductivity of water, and thus its state of being corrosive.[9] TDS showed significant association with TH, Ca^{2+}, Na^+, and Cl^-. The significant association between TDS and chloride reflects the fact that chloride is one of the principal anionic constituents of dissolved solids. Moderately positive correlations were found between hardness and Ca^{2+}, and Na^+. Therefore, it may be suggested that total hardness of the experimented water samples might be due to presence of salts of these ions.[30] There was a moderately positive association between Ca^{2+} and Na^+ and Cl^- ($P < 0.05$), and, between Cl^- and BOD_5 ($P < 0.05$). Moreover, there was a moderately positive association between SO_4^{2-} and DO ($P < 0.05$). Highly positive correlations were found between Na^+ and Cl^- ($P < 0.01$), and, between HCO_3^- and NO_3^- ($P < 0.01$).

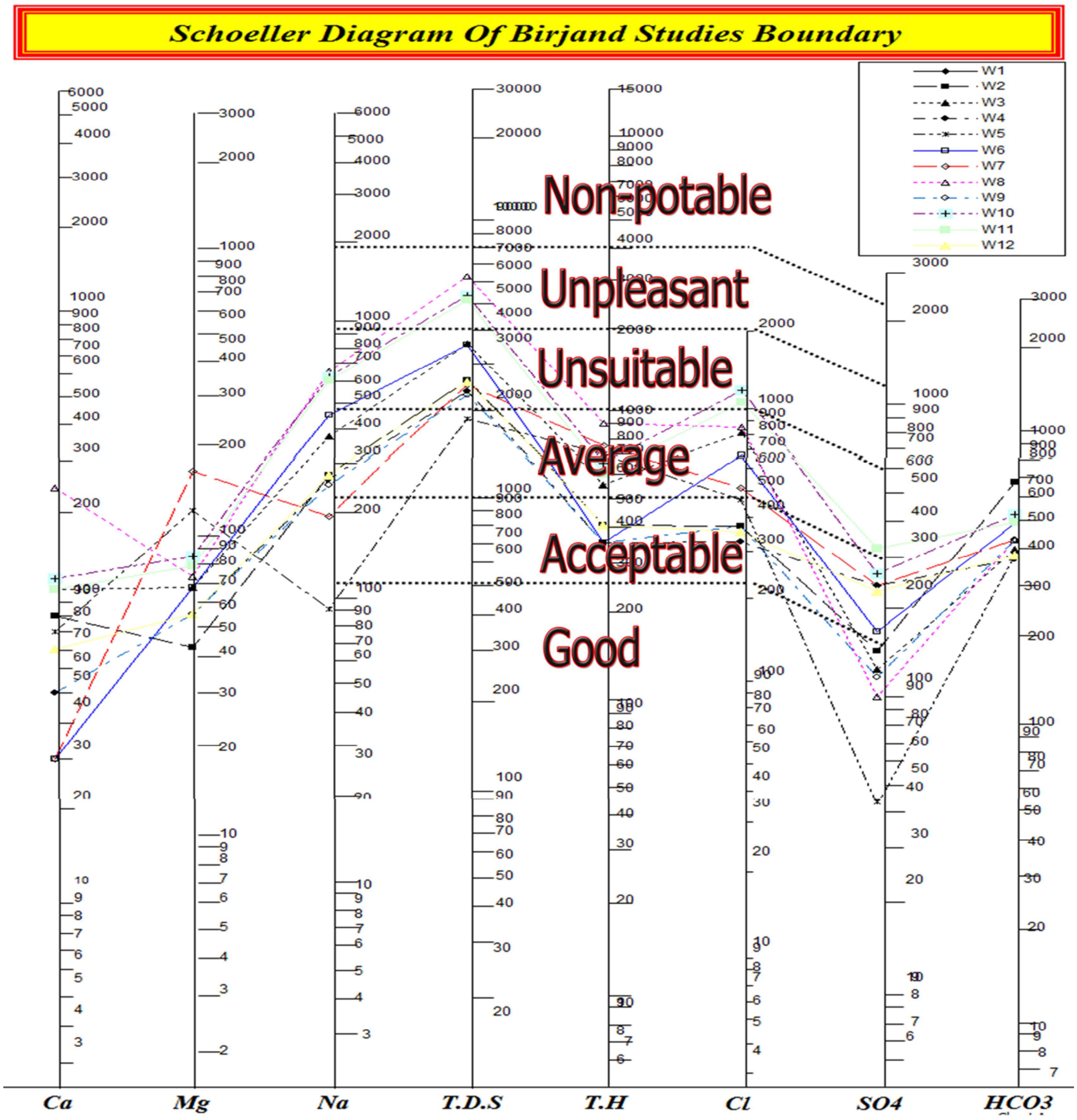

Figure 3. Schoeller diagram of Birjand, Iran f1ood plain
TDS: Total dissolved solids; TH: Total hardness

Conclusion

The results of Wilcox diagram showed that the water quality of surface water (except the station 7 and 8) was appropriate for agriculture. Moreover, the results indicated that the concentrations of EC, TDS, TH, Na^{+}, HCO^{3-} and BOD_5 in the surface water samples were above the recommended limits prescribed by the WHO guideline values for drinking water in many stations. In conclusion, the results of physico-chemical analysis of the surface water showed that water of the Birjand flood plain was suitable for agricultural irrigation.

Conflict of Interests

Authors have no conflict of interests.

Acknowledgements

Special thanks go to Mr. Gholami for their advice and guidance. The authors would like to thank Birjand Regional Water Company.

Table 3. Pearson's correlation coefficients of parameters surface water in Birjand, Iran flood plain

	pH	T	EC	TDS	TH	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	SO_4^{2-}	HCO_3^{-}	NO_2^{-}	NO_3^{-}	DO	BOD_5	COD	pH
pH	1																	
T	-0.12	1																
EC	-0.15	-0.52	1															
TDS	-0.13	-0.50	0.99**	1														
TH	-0.33	-0.48	0.63*	0.63*	1													
Ca^{2+}	-0.53	-0 29	0.77**	0.77**	0.68*	1												
Mg^{2+}	0.17	-0.31	0.04	0.02	0.63*	-0.15	1											
Na^{+}	-0.03	-0.43	0.94**	0.94**	0.34	0.65*	-0.22	1										
K^{+}	0.24	-0.08	0.15	0.15	0.24	0.18	0.13	0.08	1									
Cl^{-}	-0.18	-0.53	0.89**	0.88**	0.50	0.53	0.10	0.87**	-0.14	1								
SO_4^{2-}	0.45	-0.01	0.35	0.36	-0.07	-0.13	0.04	0.46	-0.22	0.46	1							
HCO_3^{-}	-0.27	0.20	0.19	0.17	-0.11	0.08	-0.25	0.28	0.03	0.1	0.16	1						
NO_2^{-}	0.49	-0.08	0.34	-0.6	-0.21	-0.60*	0.31	-0.32	0.5	0.30	-0.21	0.1	1					
NO_3^{-}	-0.11	0.07	0.13	0.15	-0.0	0.16	-0.18	0.16	0.54	0.01	0.0	0.73**	0.16	1				
DO	0.68*	0.17	-0.09	-0.07	-0.46	-0.39	-0.19	0.08	-0.40	-0.01	0.68*	-0.23	-0.15	-0.45	1			
BOD_5	0.11	-0.44	43	0.4	0.4	0.01	0.30	0.42	0.15	0.63*	0.3	0.16	0.27	0.1	-0.02	1		
COD	-0.24	0.23	0.13	0.12	0.24	-0.04	0.35	0.05	-0.0	0.22	-0.3	0.27	0.24	-0.16	-0.17	0.0	1	1

*Correlation is significant at P value 0.05; **Correlation is significant at P value 0.01; T: Temperature EC: Electrical conductivity; TDS: Total dissolved solids; TH: Total hardness; DO: Dissolved oxygen; BOD_5: Biochemical oxygen demand; COD: Chemical oxygen demand

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